



SCIENCE AND TECHNOLOGY

Modeling for California Water Policy Analysis

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Uncertainty Challenges Decisionmaking for California Water Resource Planning

- Water demand will exceed existing supplies more frequently in the future without appropriate policy action
- Countless uncertain factors drive future supply and demand
- 2003 Water Plan proposes numerous strategies for assuring sufficient supply to meet future demand
- Performance of options contingent upon the uncertainties
 - Water needs
 - Policy cost, effectiveness, & unintended consequences
- Hinders agreement and confidence in chosen strategies

“Predict-then-Act” Methods Can Complicate Conversations about Deep Uncertainty

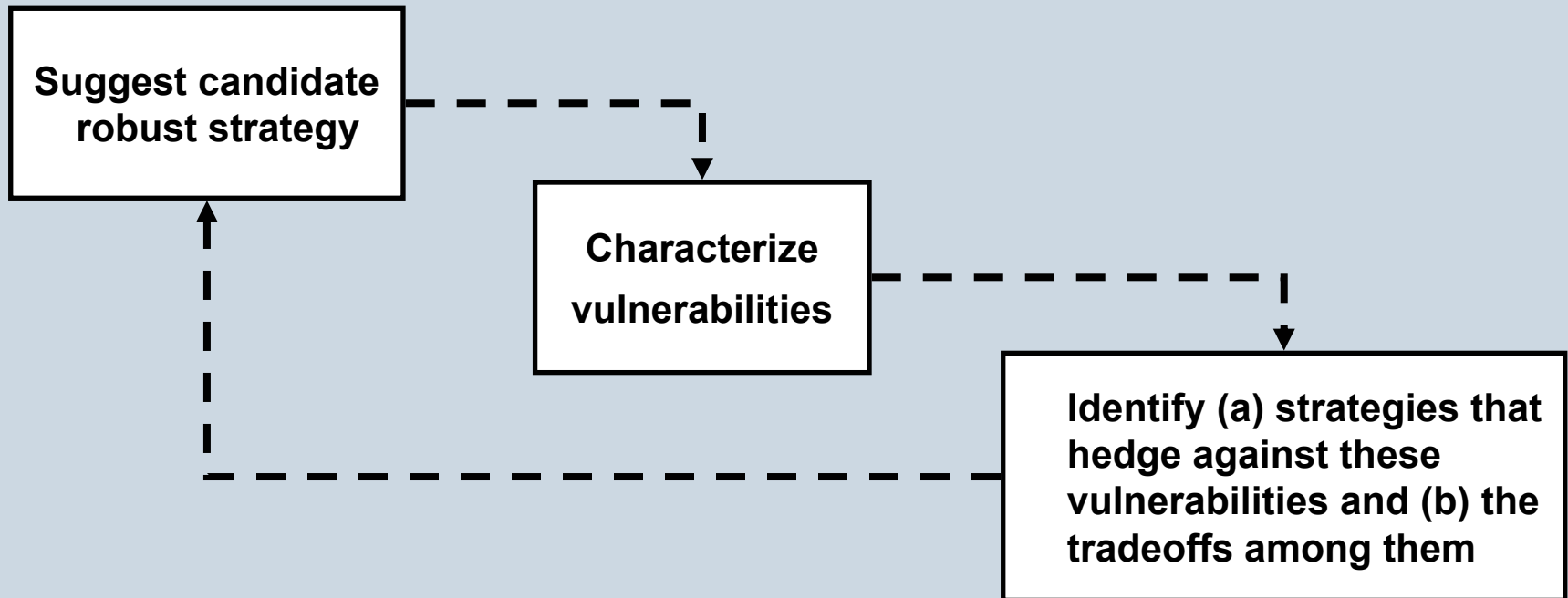
- Traditional analytic methods characterize uncertainties prior to assessing alternative decisions
 - Require estimates of probability distributions
 - Aggregate across uncertainties, imbedding them within analysis
- Decisions can go awry if decisionmakers assume risks are well-characterized when they are not
 - Uncertainties are underestimated
 - Competing analyses and assumptions lead to gridlock
 - Misplaced concreteness can blind decisionmakers to surprise

Scenarios Help Decisionmakers “See” Uncertainties

- Bring out uncertainties from within a model for decisionmakers and stakeholders to grapple with
- Leads to:
 - hedging strategies
 - new policy ideas
 - better communication about options and trade-offs
- Questions and issues remain:
 - How are scenarios selected?
 - Do they span ALL the important uncertainties?
 - Have the best new strategies been identified?

Robust Decisionmaking Uses Screening Models Generate and Evaluate Many Scenarios

- RDM is an iterative, analytic process that
 - identifies strategies whose performance is largely insensitive to poorly characterized uncertainties
 - characterizes a small number of irreducible tradeoffs inherent in the choice among such robust strategies



Robust Decisionmaking Can Help California Water Planners Consider Uncertainties

- Add rigor and objectivity to scenario selection
 - Build upon narrative scenarios in 2003 B-160
- Use scenarios to evaluate and generate robust policies
 - Adaptive
 - Diversified
 - Distributed
- Improve participation of stakeholders and decisionmakers in analysis
 - Accommodate disagreement on details and views

RDM Can Address The Following Questions

- Which supply and demand scenarios should we be concerned about?
- What combination of new supply, new facilities, use efficiency improvements, and water transfers most acceptably hedge against risks of water shortages over then next 30 years?
- How should or could California prepare for the possible effects of climate change on water resources?
- and others....

Needed: Low-resolution Water Supply and Demand Scenario Generator

- Advantages of a low-resolution model
 - Fast replicating
 - Easily modifiable and updateable
 - Understandable by decisionmakers and stakeholders
- High resolution models inform low-resolution model
 - Scenario generator as a model of models (metamodel)
- High resolution models follow-up on promising results from work with low-resolution models

A Simple Scenario Generator in Development

- General Specs

- Estimate ranges of future supply and demand
- Reflect key uncertainties and policies
- Evaluate performance of policies by cost and supply reliability

- Spatial Granularity

- By System
 - SWP deliveries
 - CVP deliveries
 - Local Imports
 - Colorado imports
- By Hydrologic Region (10)
 - Supply
 - Demand

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Reflects Often Ignored Uncertainties

- Supply
 - Rainfall and snow changes (prolonged drought and climate change)
 - Colorado River imports
 - Groundwater yield (reduced recharge & pollution)
- Demand
 - Demographic, economic, and agricultural trends
 - Use per capita, economic output, and agricultural activity
 - Environmental regulations

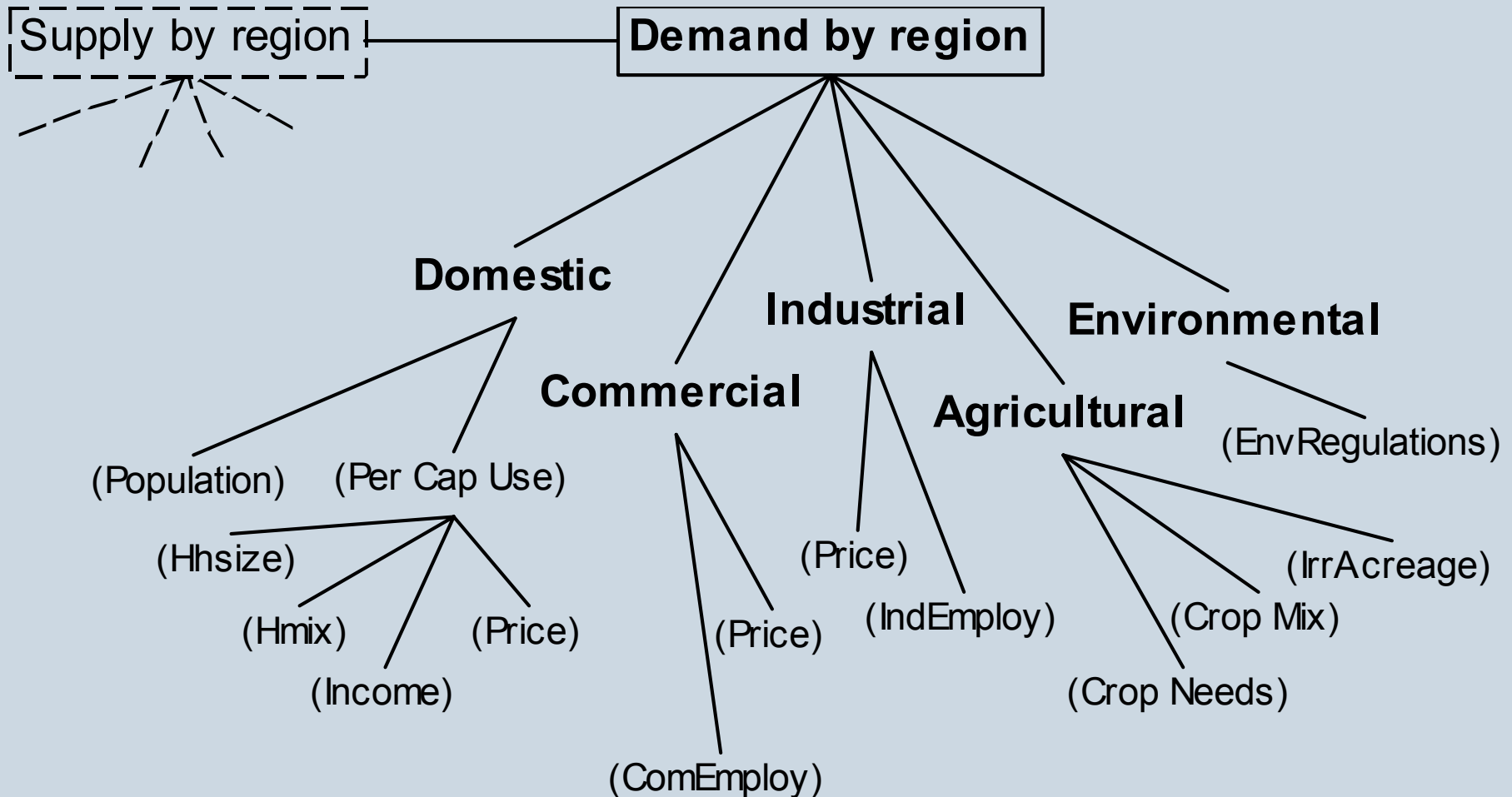
Evaluates Leading Strategies

- Supply augmenting policies from 2003 Water Plan

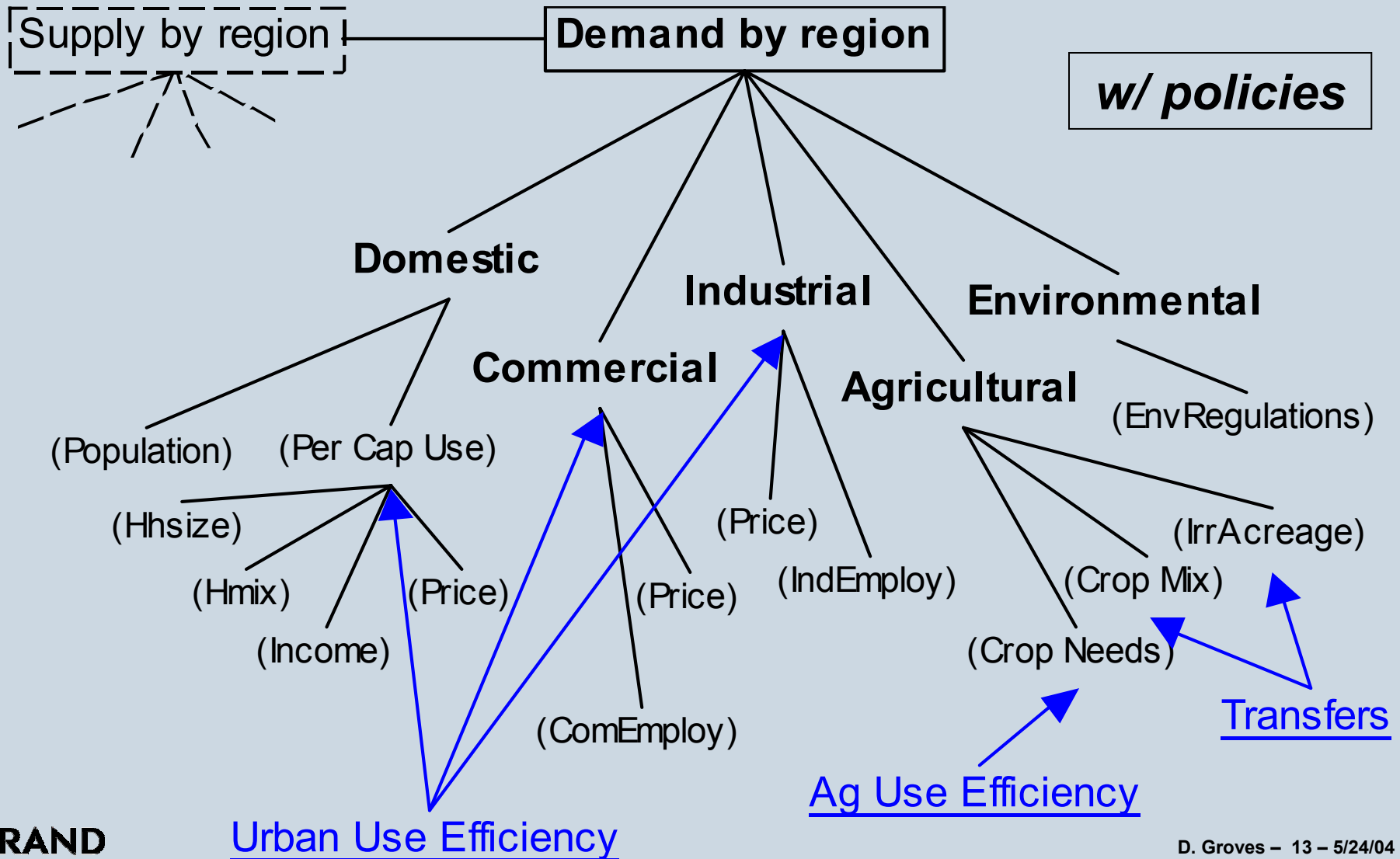
Demand	Surface Supply	Groundwater	Treated
Urban use efficiency	System reoperation	Conjunctive management	Recycled municipal wastewater
Agricultural use efficiency	Surface storage	Aquifer remediation	Desalination
Agriculture to urban transfers	Precipitation enhancement		

- Policy Timing
 - Period 1 (2005-2015)
 - Period 2 (2015-2030)

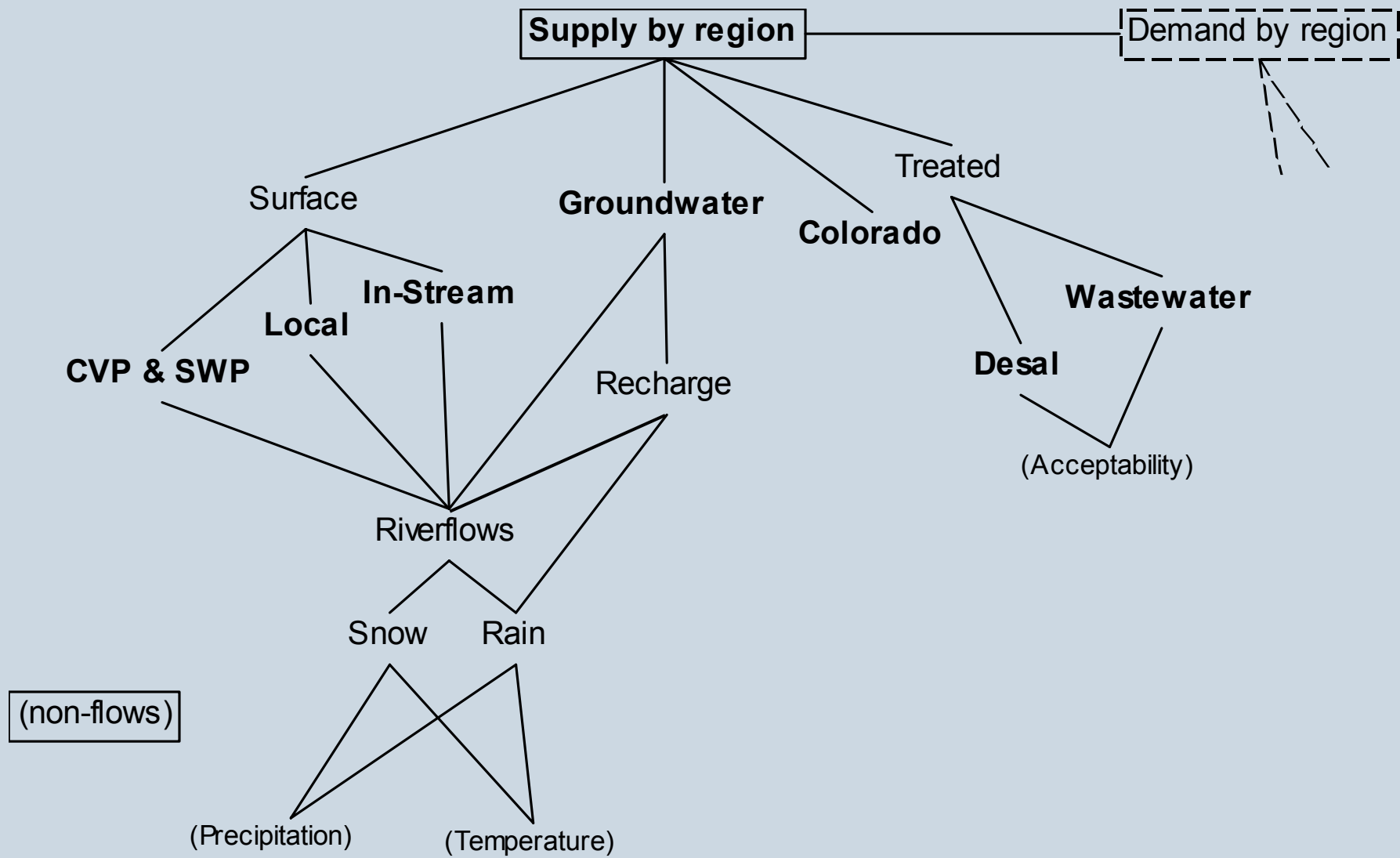
Demand Estimated Using Simple Relationships Between Factors



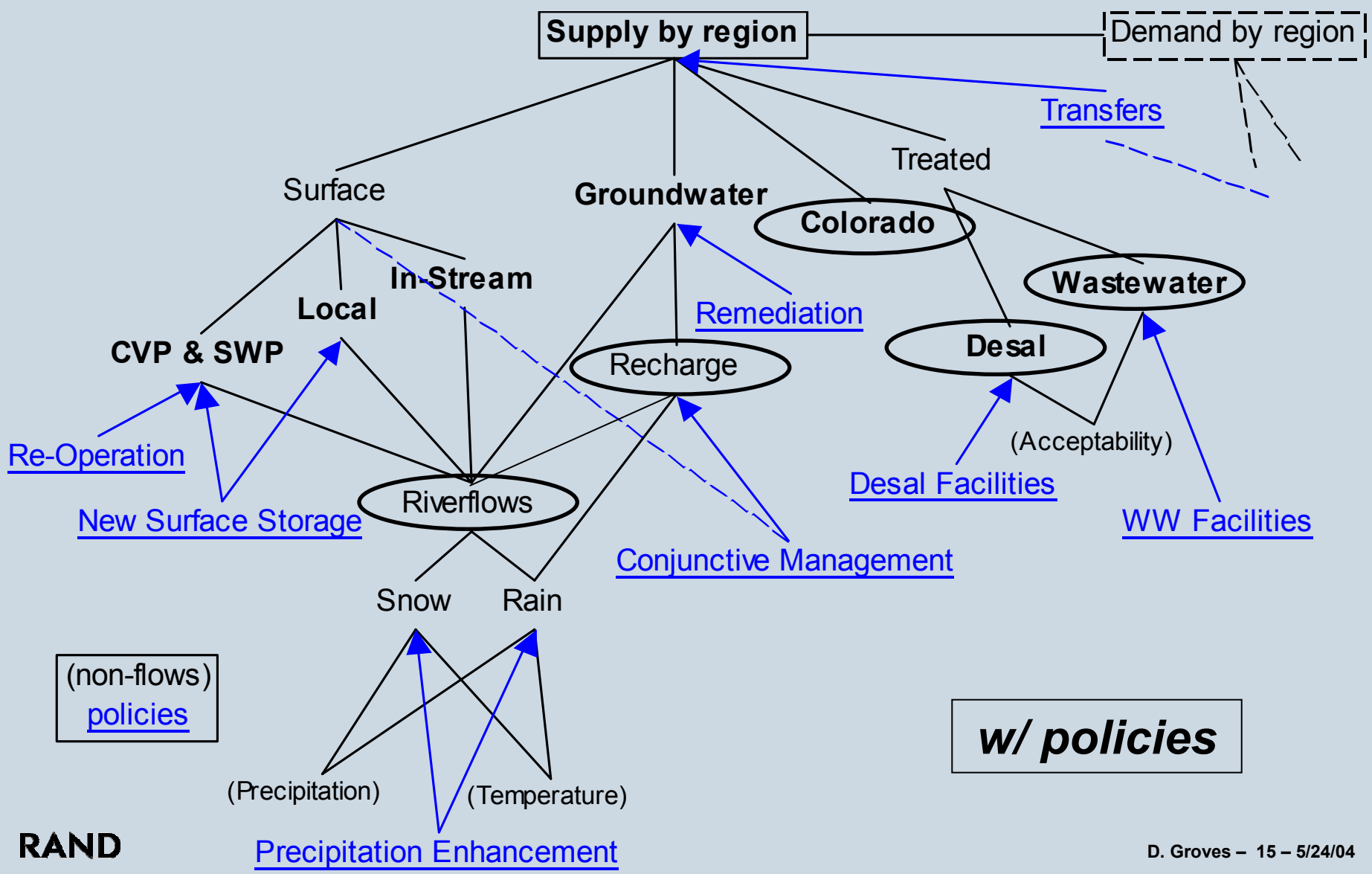
Policies Can Impact Demand



Supplies Can Be Estimated At Different Levels



Policies & relationships suggest level of detail



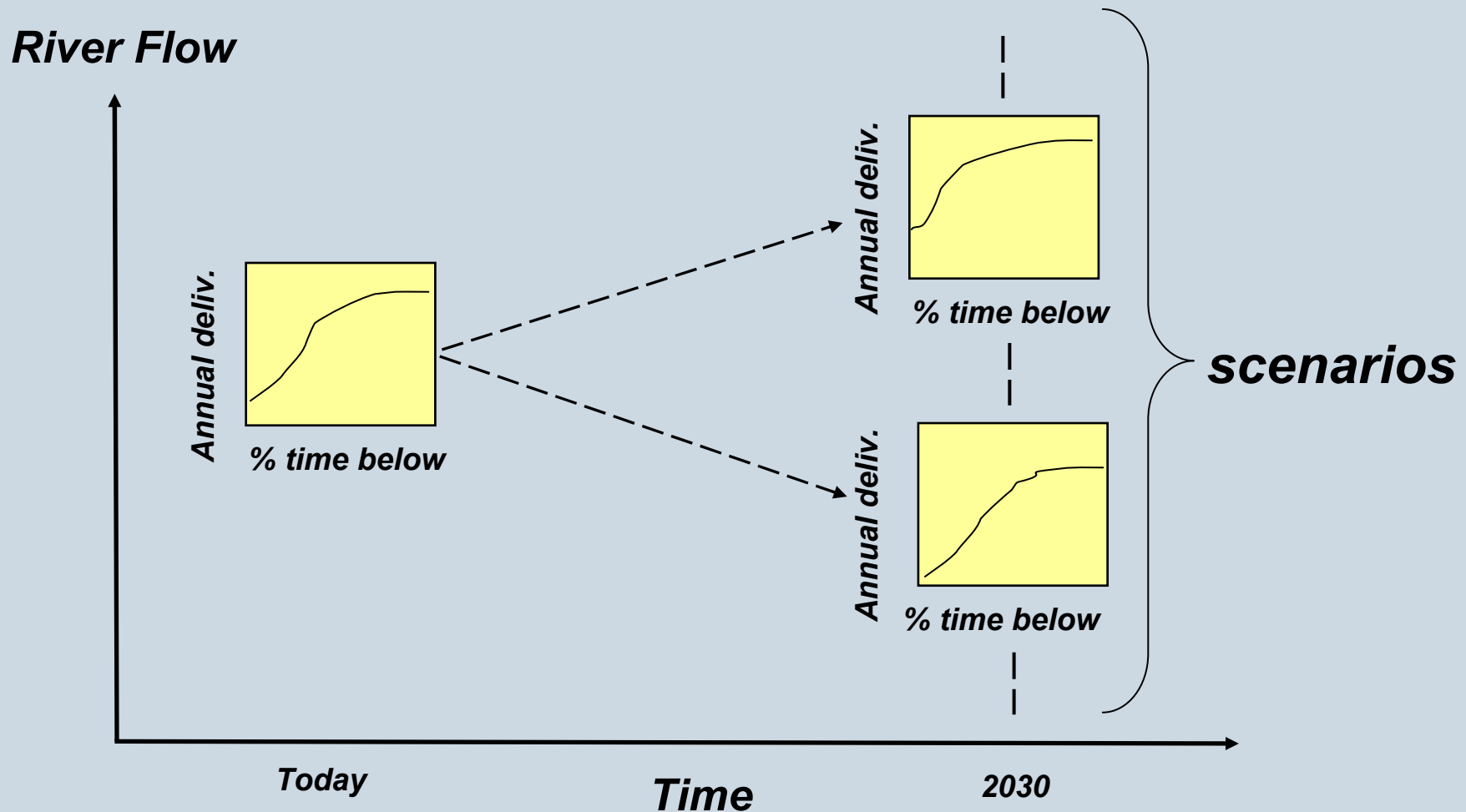
Time step, trends, and variability

- Time Step: Annually from 2000 – 2030 (easily changed)
- Trends: Uncertain trends in factors affecting water supply and demand
- Interannual supply variability is substantial
 - Option A) *Ignore it*
 - Expected supply through 2030
 - Normal and drought year supply (like previous Water Plans)
 - Option B) *Represent it using probability distribution functions*
 - Trends in other factors may affect future delivery pdfs
 - Option C) *Simulate it explicitly*
 - Each scenario corresponds to a simulated hydrology
 - Scenarios reflect background variability AND uncertainties about trends

PDFs Characterize Variability But With Important Limitations

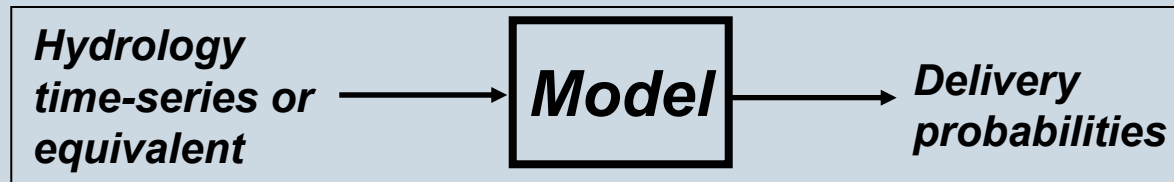
- 1) Using PDFs assumes stationarity (the future will be like the past)
- 2) Extremes of the PDF are based on small samples
- 3) Assume time ordering of events is not important
 - Poor assumption for California water resources

Relax Stationarity Assumption with Alternative PDFs



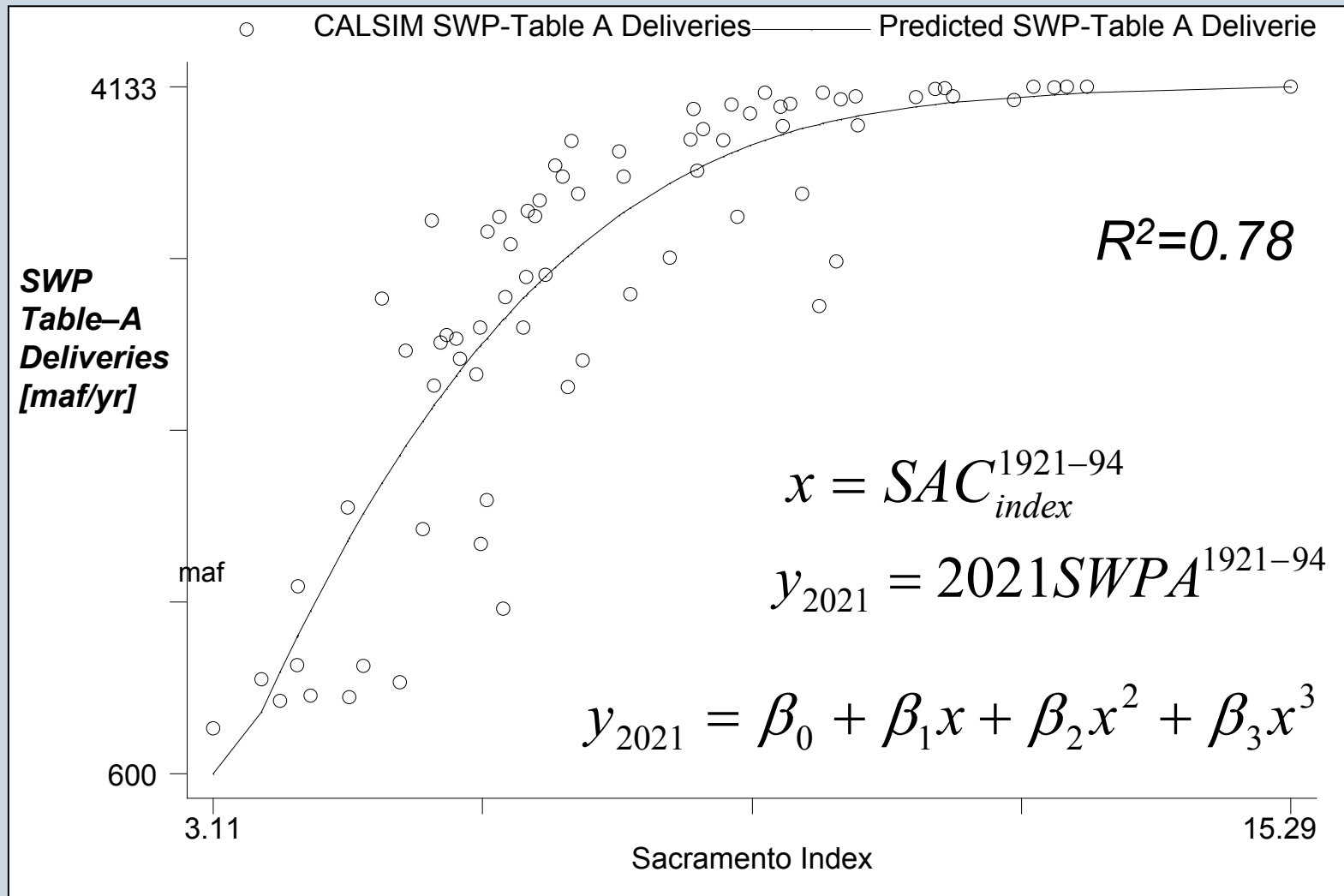
Use Models to Generate Alternative PDFs

- SWP and CVP: ~ 20% of non-environ. supply
 - Delivery variability largely explained by variability in the flows of the rivers feeding into the Sacramento and San Joaquin Rivers.
 - To generate scenarios of future deliveries:

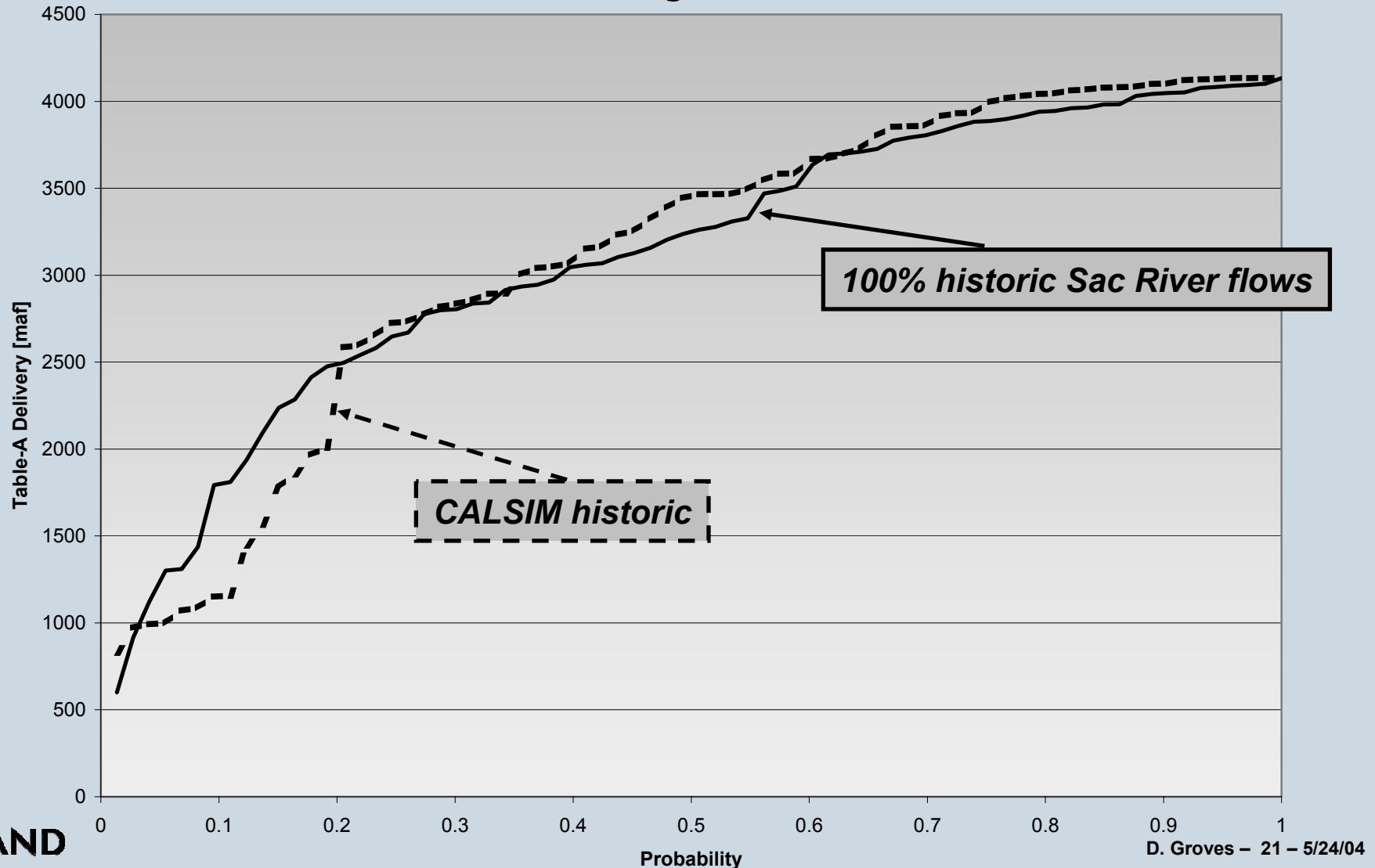


- “Model” could be CALSIM or more simply heuristic
 - Example: one based upon the Sacramento River Index

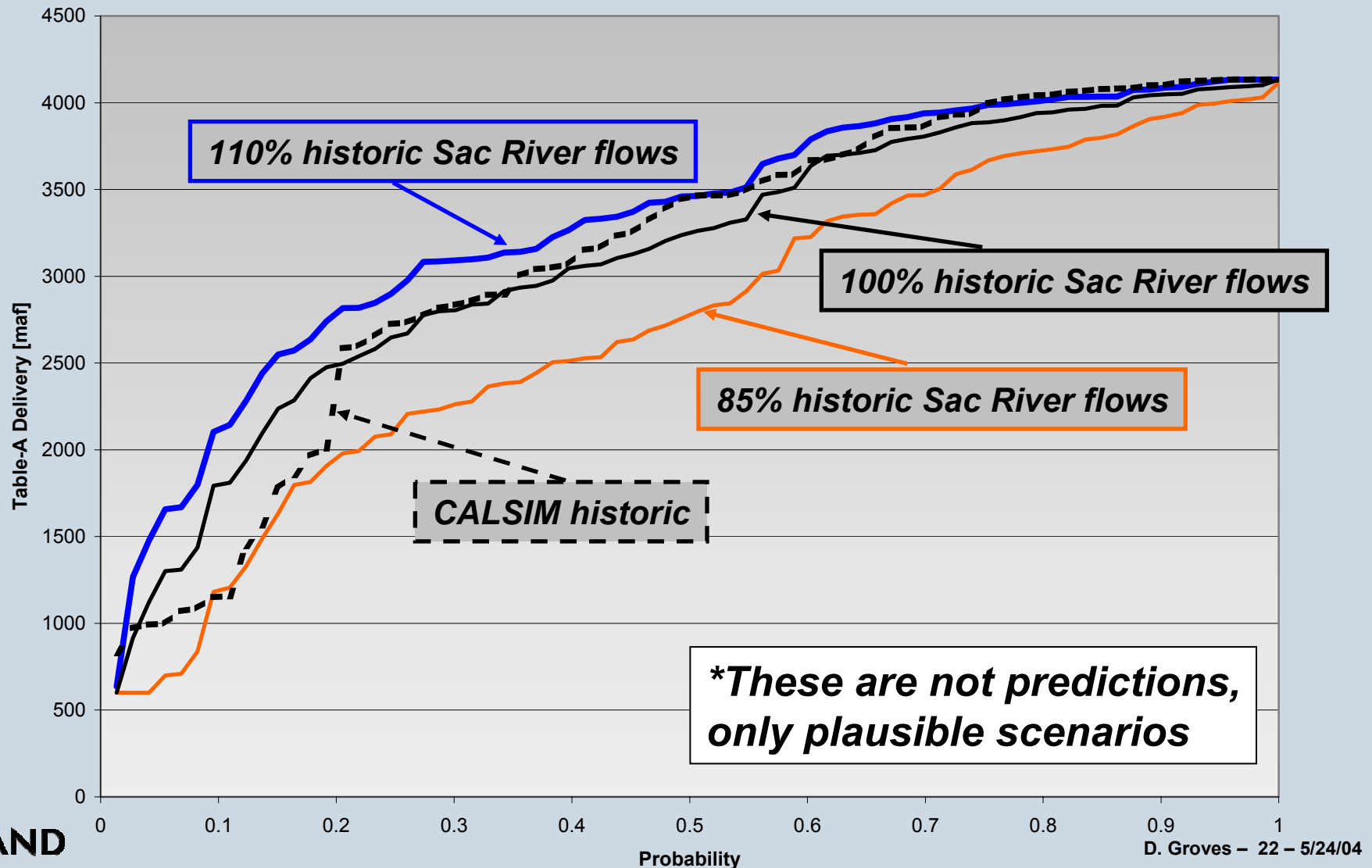
Sac River Index Can Explain 78% of CALSIM-Modeled Variance in SWP Table-A Deliveries



Approximate CALSIM-estimated SWP Table-A delivery PDF with heuristic



Create delivery scenarios via parametric variation of Sacramento River Index



Demand Components and Factors

Demand	Factors	Uncertain Trends	Policy Levers	
Urban				
Single Fam	<u>SF Homes</u>	Geometric	Urban WU Efficiency	
	<u>per home use</u>	Geometric		
	Multi Fam	<u>MF Homes</u>		Geometric
	<u>per home use</u>	Geometric		
	Commercial	<u>Comm. Employment</u>		Geometric
	<u>per employee use</u>	Geometric	Urban WU Efficiency	
Industrial	<u>Indust. Employment</u>	Geometric		
	<u>per employee use</u>	Geometric		
Public	<u>Total Population</u>	Geometric		
	<u>per capita use</u>	Geometric	Urban WU Efficiency	
Agricultural				
Water Use by Crop	<u>Irrigated Acreage</u>	Linear	Water Transfers	
	Applied Water			
	<u>Consumed Fraction</u>	Geometric	Water Use Efficiency	
	ETAW			
	<u>Effective Precipitation</u>	Related to supply		
	Evapotranpiration			
	<u>ET Yield</u>	Linear	Water Use Efficiency	
	<u>ET Irr. Method</u>	Linear		
Environmental				
Bay-Delta	Environmental Regulations	Discrete changes	Change Regulations	
Wild & Scenic	W&S River Flows	N.A.	N.A.	

Supply Components and Factors

Supply	Factors	Uncertain Trends	Time Variability	Policy Levers
Surface				
CV Projects	Sac. River Index	Linear	Delivery PDFs	Dam Reoperations Surface Storage Precipitation Enhancement
SWP				
CVP				
Local Imports	Tuolumne River Flow	Linear	Delivery PDFs	Precipitation Enhancement
Hetch Hetchy				
EBMUD				
LA Aqueduct	Mokelumne River Flow	Linear	Delivery PDFs	Precipitation Enhancement
Local	Mono & Owens Runoff	Linear	Delivery PDFs	Precipitation Enhancement
In-stream	Precipitation Indices	Linear	Precip. PDFs	Precipitation Enhancement
Delta	Sac. River Index (Supply = Env. Demand)	Linear	Delivery PDFs	N.A.
Wild & Scenic		N.A.		
Groundwater				
Aquifers	Recharge	Linear	Average	Conjunctive Use Aquifer Remediation
	Precipitation			
	Artificial recharge			
	Pollution Loads	Linear		
Imports				
Colorado River		Linear	Yield PDFs	
Treated				
Treated Wastewater	Facilities	Linear	Average	New Facilities
	Acceptance	Linear	Average	
Desalinated	Facilities	Linear	Average	New Facilities
	Acceptance	Linear	Average	

Next Steps

- Approximate other deliveries from CALSIM runs
 - SWP non-Table-A
 - CVP
 - Local imports (e.g. EBMUD, SF, and LA)
- Parameterize policy impacts upon supplies
 - How would new surface storage affect PDFs
- Alternatives
 - Identify better model to drive delivery probabilities (CALSIM Allocation Model?)

RDM Example

RDM Manages Complicated Problems Without Assumptions of Predict-Then-Act

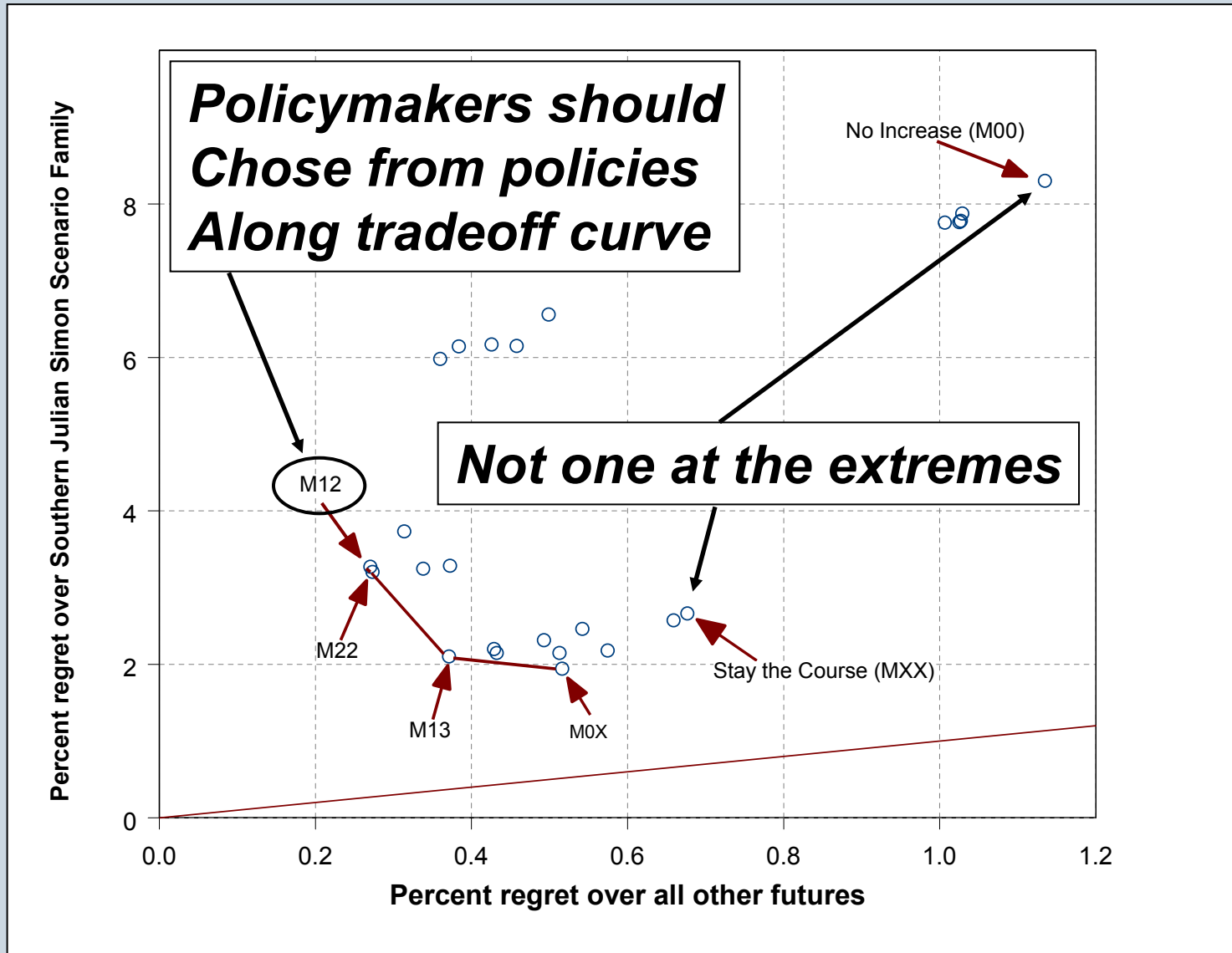
“What near-term actions will help ensure strong economic growth and a healthy environment over the course of the 21st century?”*

- Used “Toy” systems-dynamics model with
 - 41 input parameters representing uncertainties about
 - future economic, demographic, and environmental trends
 - values and capabilities of future decisionmakers
- Value functions based loosely on UN Human Development Index, which reflects interests of a range of stakeholders
- Considers policies for limiting GHG emissions in the North and South

Through an Iterative Process RDM Identifies Better Policies

- Across hundreds of thousands of plausible scenarios, identifies a robust policy:
 - Strict emissions controls in North
 - Moderate emissions controls in South
 - “Balanced approach to sustainability”
- Even this policy fails in some plausible futures
 - Statistical techniques identify stressing futures
 - When emission controls are too stringent or unnecessary
 - Concern of the industrialists and/or climate change contrarians

RDM Identifies Tradeoff Curve of Policies



RDM Then Suggests Improved Policies

- Analysis then suggests better policies to hedge against identified uncertainty
 - Add cost constraints (safety-valves)
- New vulnerabilities are identified and new tradeoffs curves are revealed
- Each iteration:
 - Identifies ever-improving policies
 - Reveals those uncertainties most important to decisionmakers